LemurDx: Objective Measurement of Hyperactivity With Mobile Sensing, Machine Learning, and Context Modeling

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Background

- Current Problems with Measuring Hyperactivity
  - Reliance on parents' / teachers' subjective answers

	Inattentive	Hyperactive
Objective Measure	✅	

=> Need to add objectivity to the diagnosis and measurement of hyperactivity.

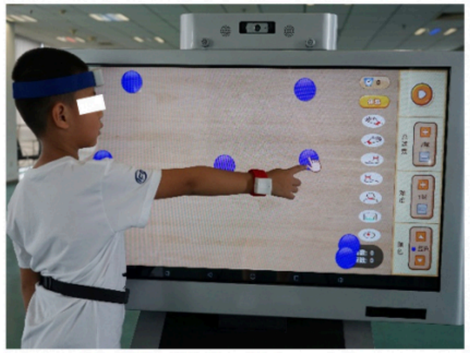
We want to make a tool that supports doctors' decision making.

Background

Related Work

Jiang et al. (CHI'20)


(1) Schulte grid

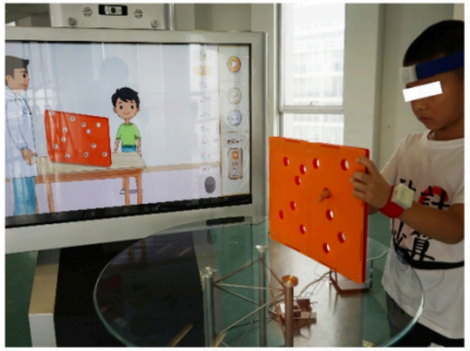

(2) Multi-ball tracking

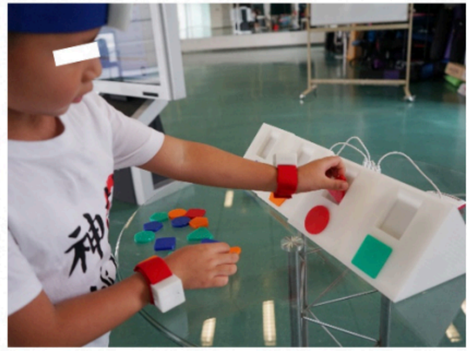

(3) Catching grasshoppers

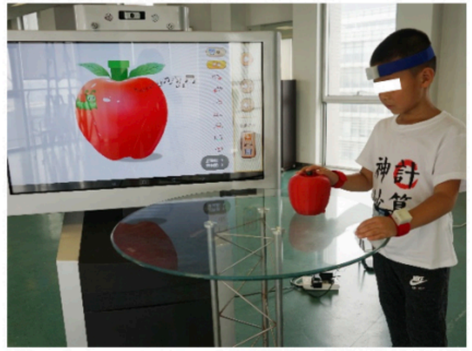

(4) Drinking birds


(5) Limb reaction


(6) Reading


(7) Finger holes


(8) Shape-color conflicting


(9) Catching worms


(10) Keeping balance

=> Measurements happened during specific times.

Our Goal

Hyperactivity detection from smartwatches' data worn by children freely in their daily lives to enable a longer-term monitoring of children.

=> Challenge: lack of context in the motion data

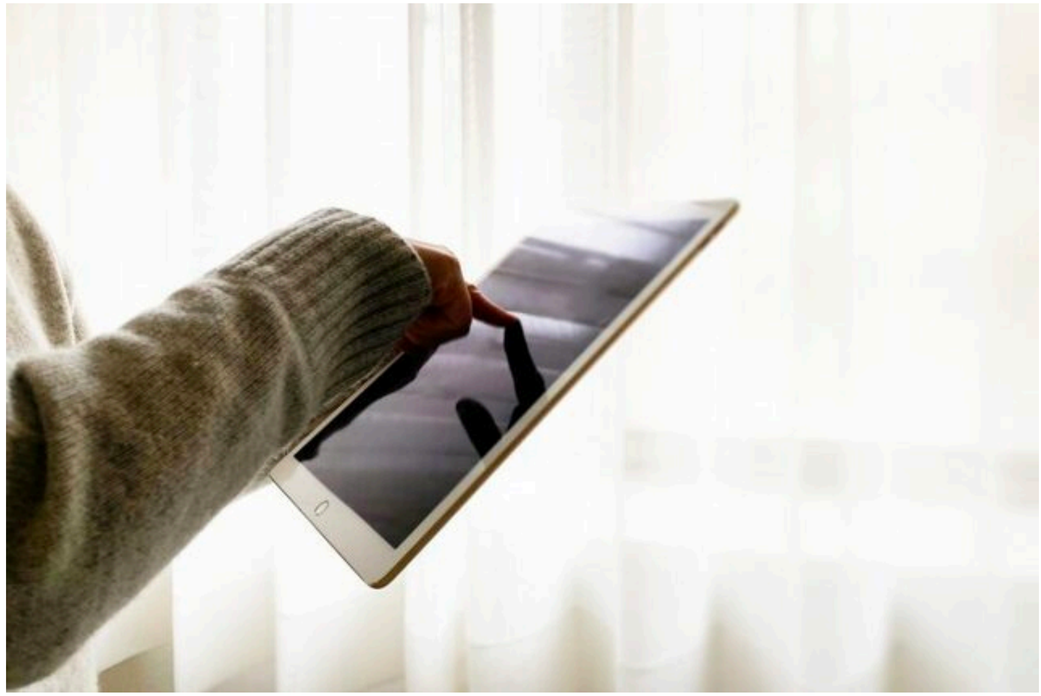
=> We leverage machine-learning (ML)-based approach to contextualize motion data.

Data Collection

- Smartwatch App
  - acceleration at 50 Hz
  - Heart rate
  - GPS
  - Bluetooth device

Data Collection

- Activity Context
  - Sleeping
  - Sitting/Quiet
  - Everyday/Household
  - Exercise
  - At school
  - Not wearing
  - Other



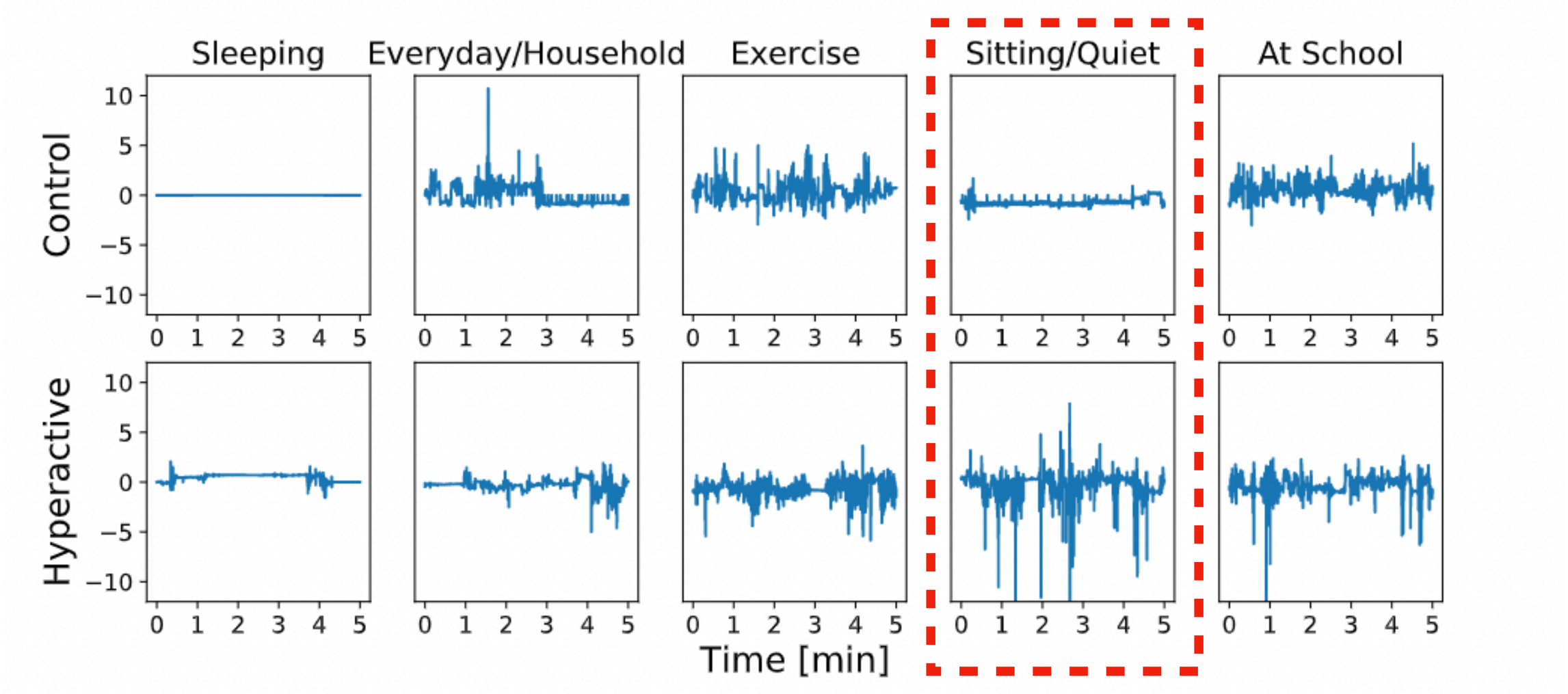
- Reported at the end of each day, with 30 minutes granularity

Data Collection

- Participants
  - 5 - 12 years
  - 68 completed
    - 32 ADHD, 36 Control
    - Criteria: K-SADS-PL, VADPRS

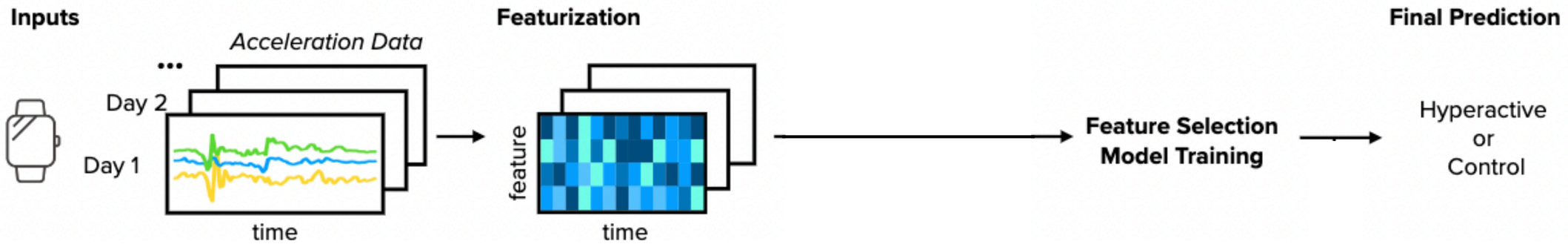
- Data Cleaning
  - 61 participants
    - 25 ADHD, 36 Control

Data Collection: randomly-extracted examples

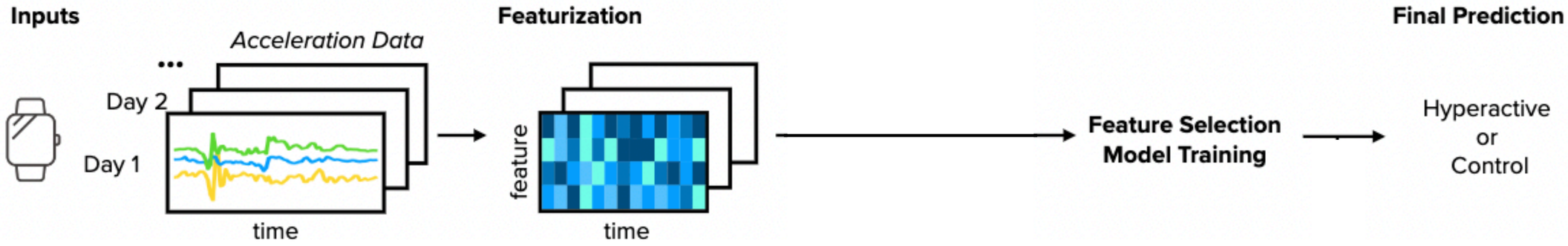


Importance of making ML models aware of activity context

Baseline

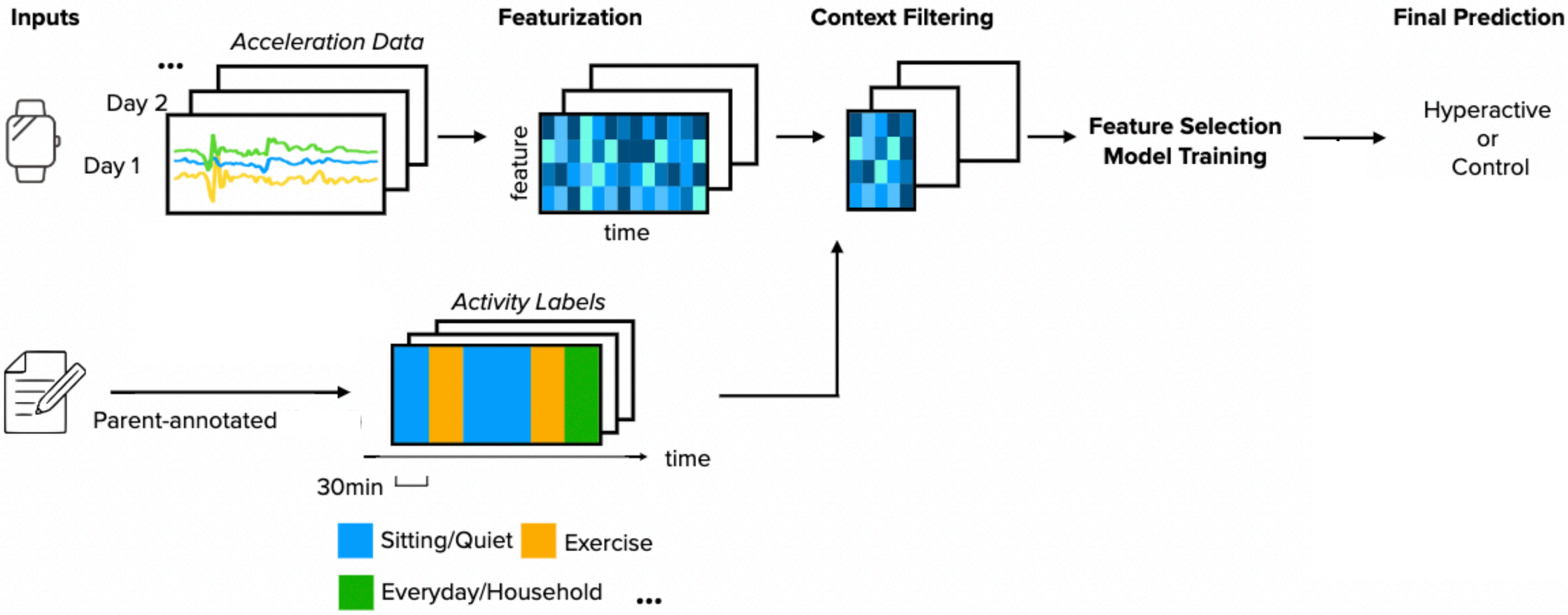

Inputs
Acceleration Data
Day 2
Day 1
time
Featurization
feature
time
Feature Selection
Model Training
Final Prediction
Hyperactive
or
Control

Baseline (Results)

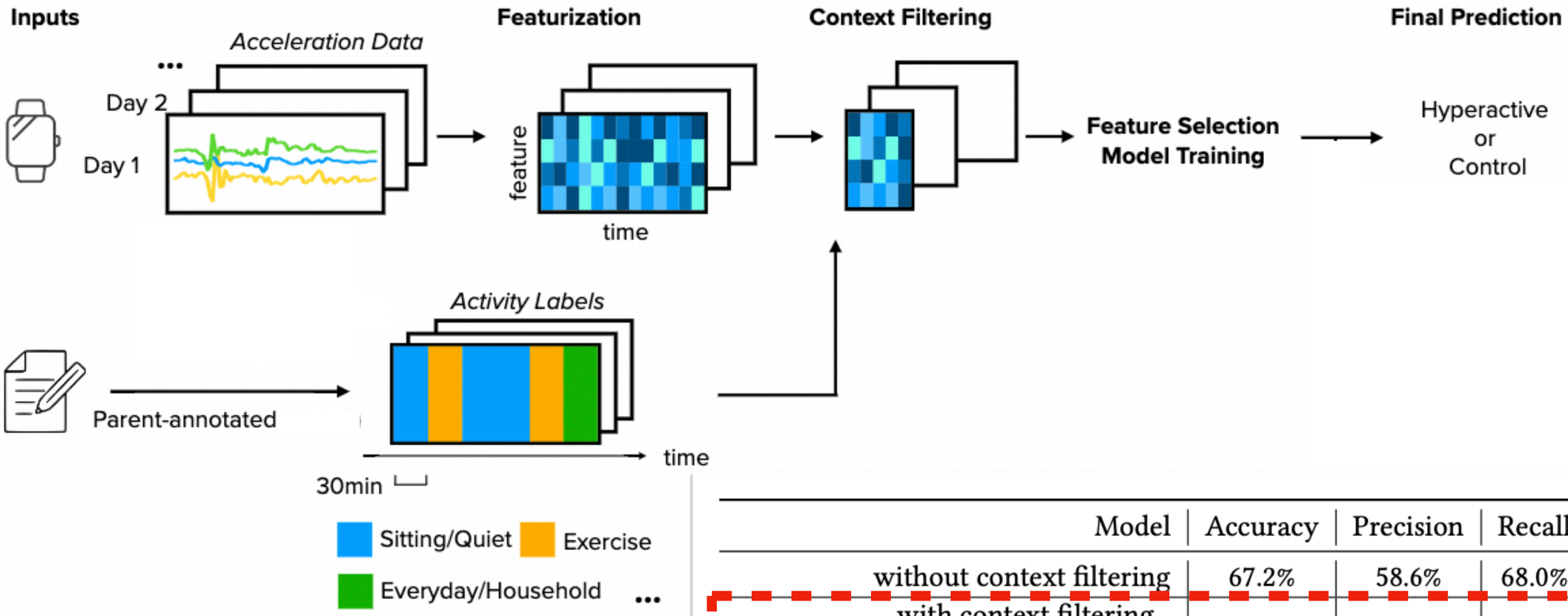


Model	Accuracy	Precision	Recall	F1 Score
without context filtering	67.2%	58.6%	68.0%	63.0%

With context filtering using parent-annotated labels

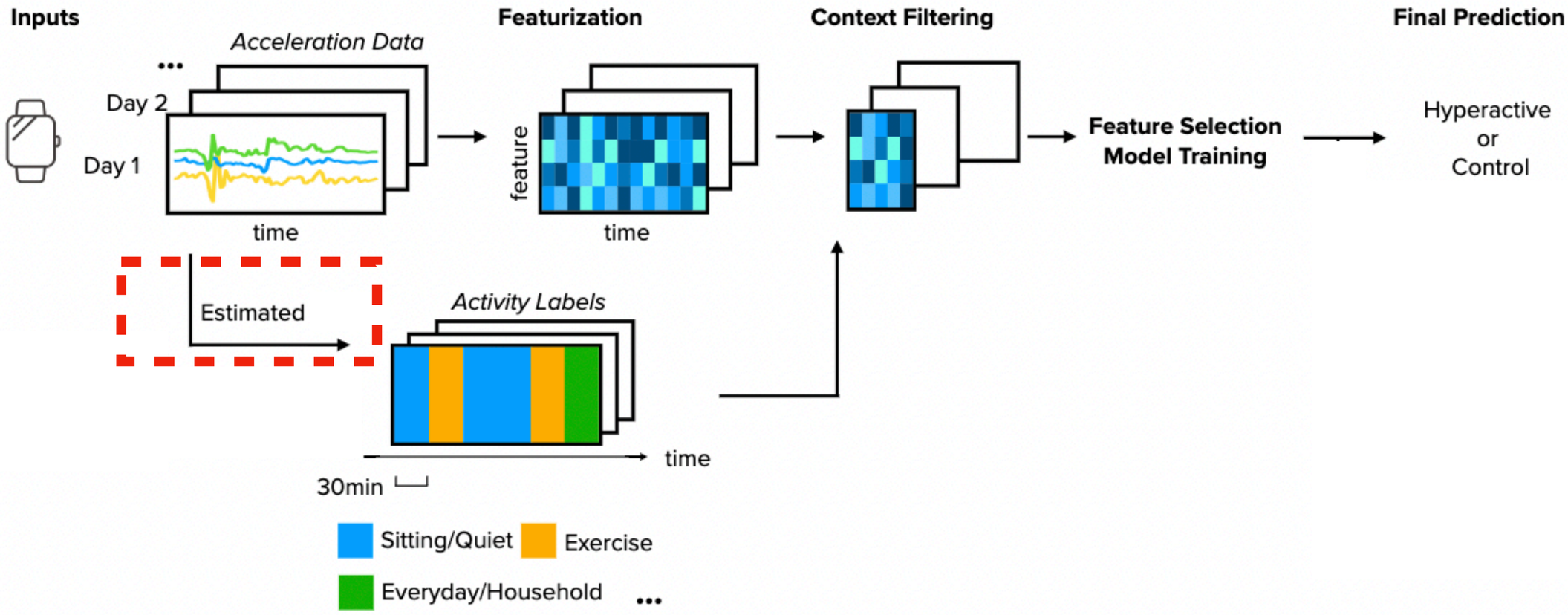


With context filtering using parent-annotated labels (Results)



Model	Accuracy	Precision	Recall	F1 Score
without context filtering	67.2%	58.6%	68.0%	63.0%
with context filtering (parent-annotated activity labels)	85.2%	83.3%	80.0%	81.6%

Approach + Results



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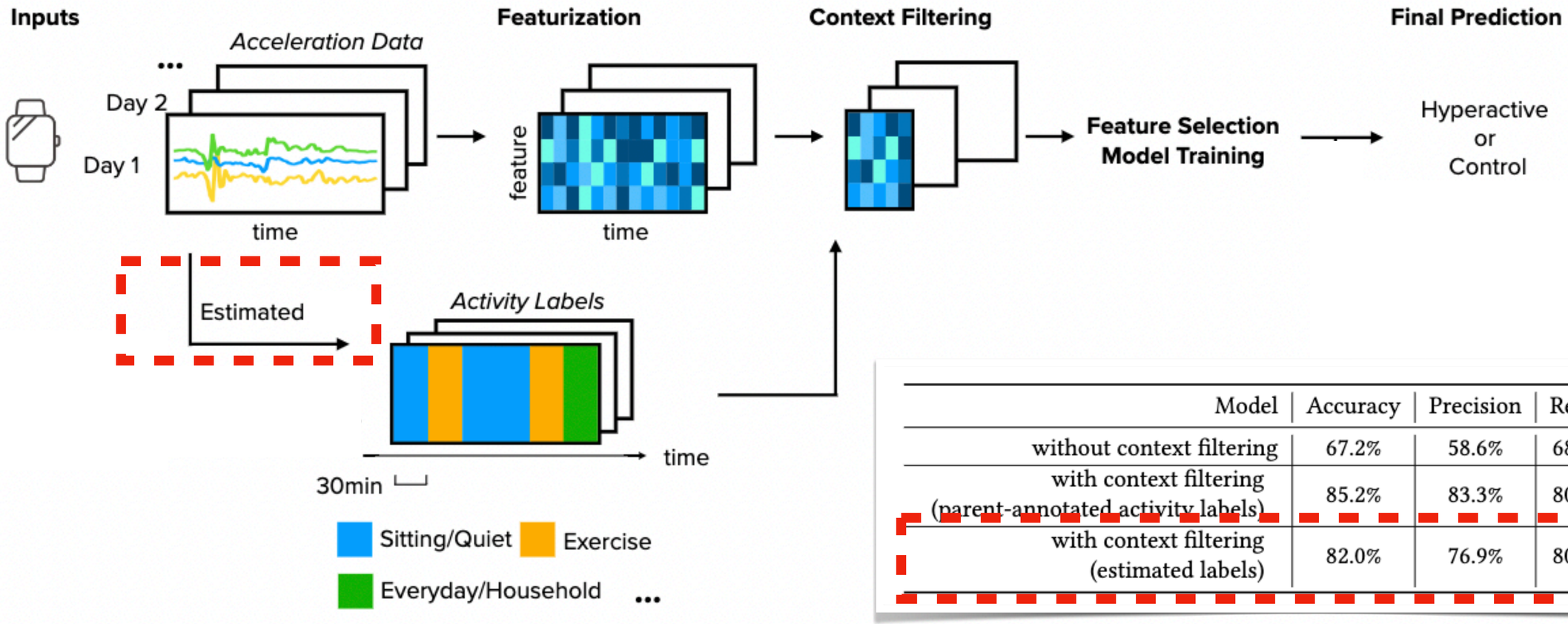
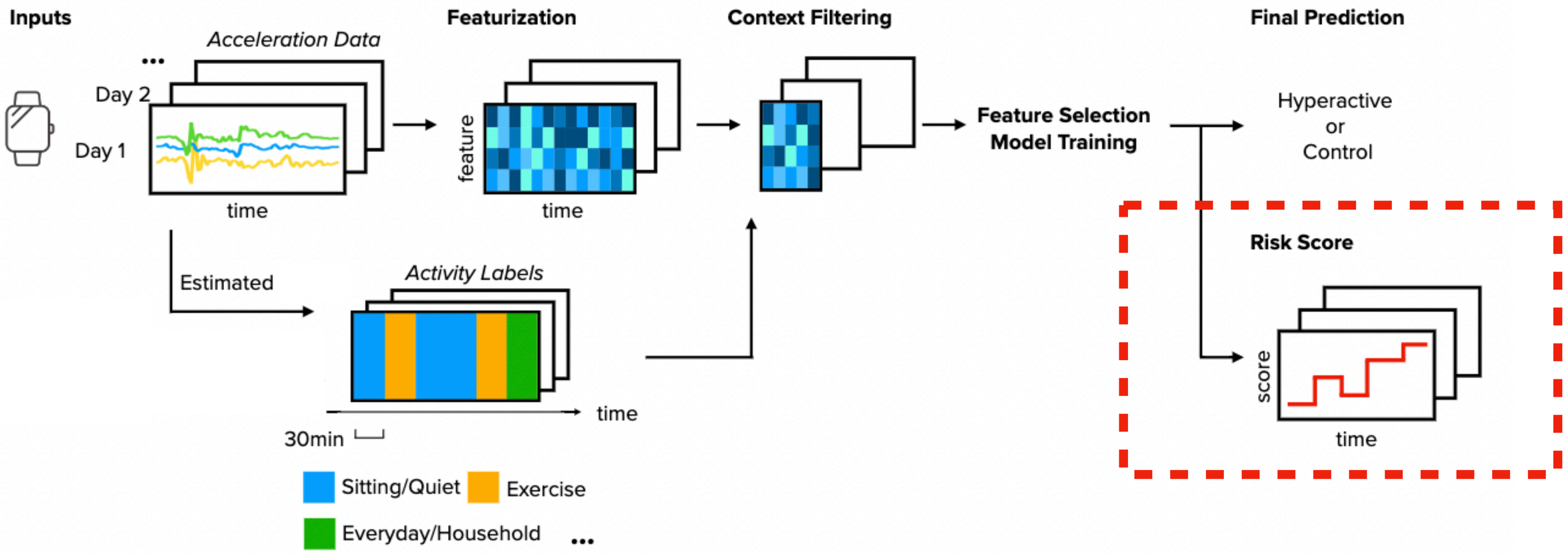


Model	Accuracy	Precision	Recall	F1 Score
without context filtering	67.2%	58.6%	68.0%	63.0%
with context filtering (parent-annotated activity labels)	85.2%	83.3%	80.0%	81.6%
with context filtering (estimated labels)	82.0%	76.9%	80.0%	78.4%

Risk Score


Inputs
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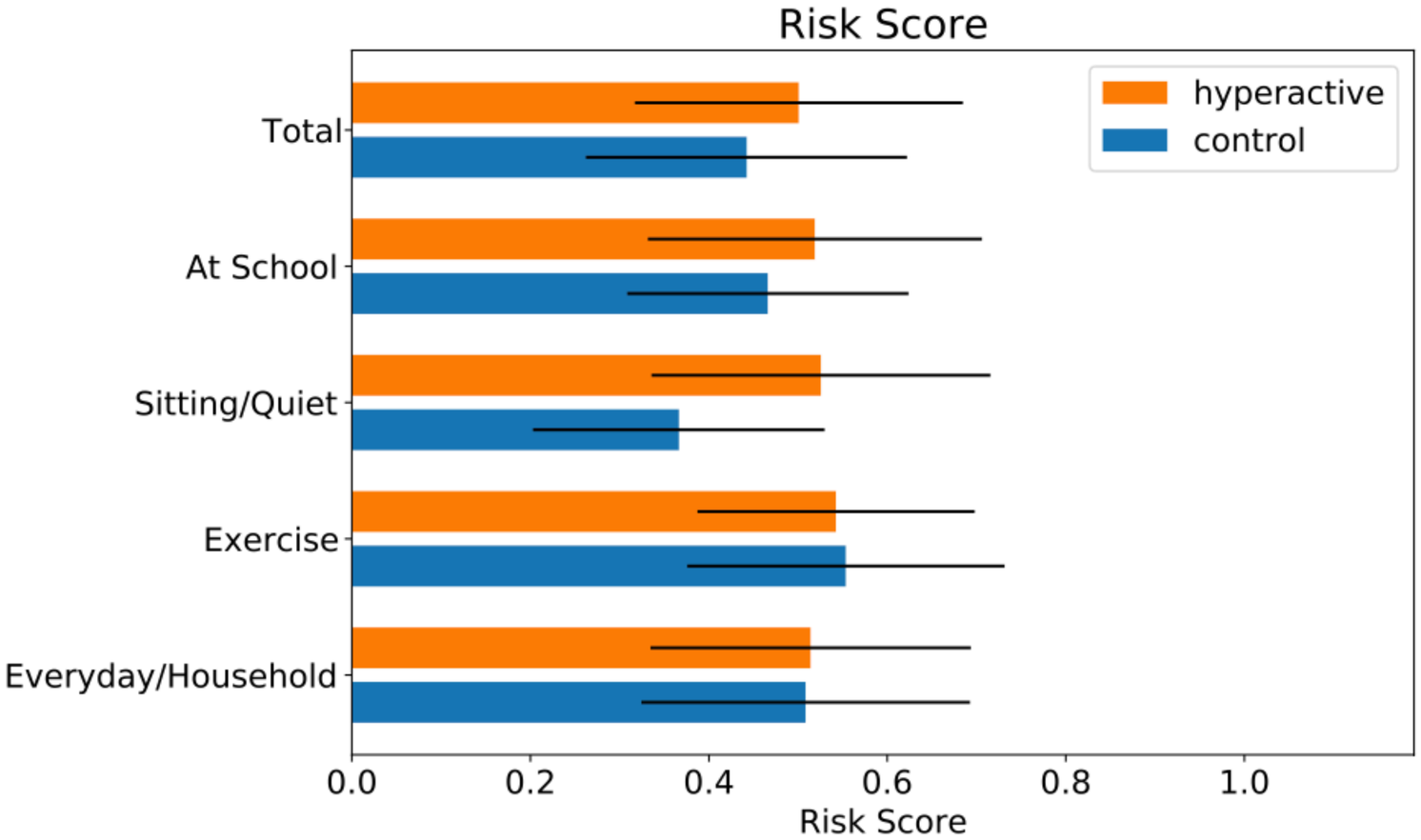
Control
Risk Score
score
time
Estimated
Activity Labels
time
30min
Sitting/Quiet
Exercise
Everyday/Household

Result

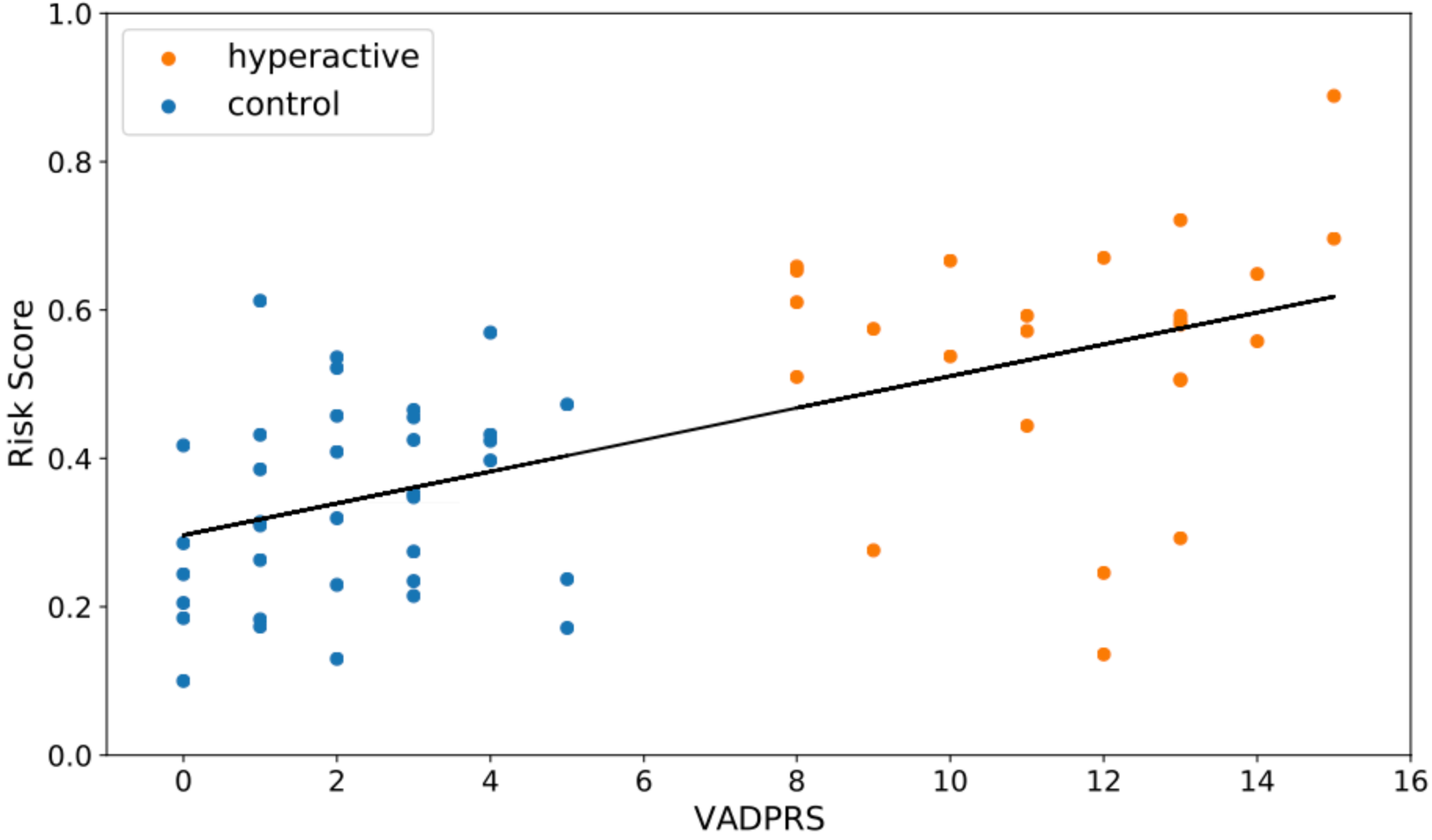
Error bar: standard deviation



※ We used parent-annotated labels for generating this graph.

Result

Coefficient ~ 0.3



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Interface Design

Summary

- collected data using Apple Watch in **an unconstrained setting with 61 participants.**

- demonstrated that **context filtering based on parent-annotated activity labels is effective**, achieving 85.2% (F1 score = 81.6%) accuracy.

- **enabled the pipeline to estimate the activity context from motion data only** to achieve a fully automated detection system, which achieved 82.0% (F1 score = 78.4%) accuracy.

- analyzed the result of the model based on the risk score and **designed an initial interface to help clinicians make decisions.**
  - Our next step is the deployment and evaluation of the interface.

Acknowledgements

- National Institute of Mental Health (R41MH119644)
- PINch